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Development of Downlink Communication System for Steerable Drilling Application

Dang Rui-rong, Yin Guang, Gao Guo-wang, Liang Lu*

Key Laboratory of photoelectric logging and detecting of oil and gas, Ministry of Education Xi'an Shiyou University, Xi'an 710065, China

Abstract

In order to improve the reliability of information transmission in steering drilling system, the downlink instruction encoding and decoding based on the transmission mode of mud pressure pulses were researched. According to analyze the characteristics of mud pressure pulses, the scheme applied negative pulses to transmit downlink instructions was established. Furthermore, the receiving system which identified instructions by detecting the time difference between falling edges of adjacent pulses was developed. A series of field experiments have been conducted by using the system. Experimental results show that the download instructions applied the mud pressure negative pulses can be decoded reliably and the recognition ability of instructions is improved considerably.

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Key words: steerable drilling; drilling fluid pulse; instruction downlink; pressure acquisition;

1. Introduction

Steerable drilling technology is an advanced topic in the field of petroleum drilling engineering. With the automatic regulation function, steerable drilling system can track and drill the target reservoir. In other words, it can trace the "reservoir's odour" and successfully resolves the control problem of well trajectory in complex conditions. Compared with conventional drilling techniques, steerable drilling system reveal many obvious advantages.

The bidirectional communication between downhole and drilling platform, which is one of the core technologies of oriented drilling, plays a very important role in steerable drilling engineering. But in China, there is no mature technology in downlink communication currently. Through the investigation of existing technology domestic and foreign, in this paper, new command encoding method whose software and hardware of downlink communication system are developed and tested.

2. Drilling information transmission

* Corresponding author. Tel.: +86-13572494967;
E-mail address: tom_yin756@qq.com

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Drilling information transmission contains wired and wireless method. The media of wired method mainly include cables, special drill pipe, optical fiber. And the wired method can realize high speed bidirectional data transmission between downhole and ground. But it still exist the disadvantage of complicated structure, complex operation and high cost, so many countries research wireless transmission while drilling system actively.

Wireless transmission while drilling system achieve two-ways drilling information transmission without physical connection. At present, it falls into several categories: electromagnetic style, acoustic type and mud pressure pulse method. And many countries have done a lot of research in the first two methods, but there are still some defects that the key problems aren't solved completely. Therefore, the practical application of them are constrained severely. The drilling mud is used as the transmission media to transmits information by identifying the changes of the flow of drilling mud produces pressure fluctuation. This method has no especial requirements and limits to the technology of drilling tools, and it also reduces the development costs. Moreover, it has little effects to normal drilling operations and it is reliable in long-distance transmission. So, it is widely-used in steering drilling system.

3. Downlink instruction encoding

Drilling fluid pulse is divided into positive and negative pulse. Considering the depth, rate and reliability of the downlink communication transmission of steerable drilling system and the working characteristics of the downhole tools, the drilling mud negative pulse is used to send instruction in this paper.

After the research of drilling fluid negative pulse waveform (figure1), we find that the falling edge time of the pulse is shorter than the rising edge time. Considering the recognition accuracy, transmission time of downlink commands, the feasibility of the drilling process and other requirements, new instruction encoding method is put forward which using pressure pulse falling edge and the difference between adjacent drops pulses on time. Figure2 is the structure of downlink instruction encode.

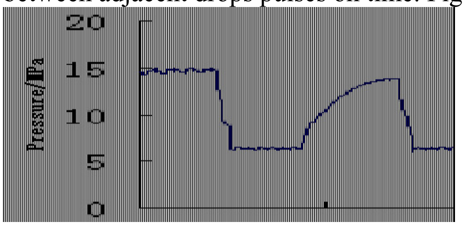


Figure1 The waveform of drilling fluid negative pulse

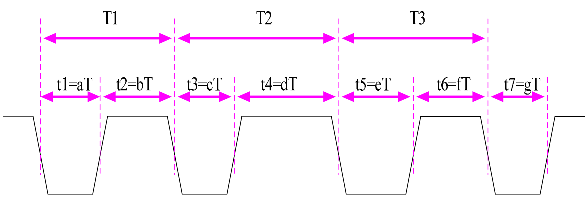


Figure2 Structure of downlink instruction encode

In figure2, pulse T1 is the header of the downlink instruction, and pulse T3 is the tail. Pulse T2 is a key part of the instruction. The length of Pulse T2 is used to distinguish different instructions. The experiment demonstrates that the minimum falling edge time is 2 seconds. Taking into account the production and the detecting error of fall edge, T is taken as 5 seconds. The value of t1~t7 are taken as integer multiple of T, and the values are fixed except t4. The b is taken as integer 2. In order to distinguish the head and the tail, t6 is taken as 3T. The values of a, c, e and g are taken as the integer 2. The value of d can take the integer 2~11 to show ten different commands. The table1 shows the relationship between time length of T2 and instruction.

Table1 Time length of T2 *VS* Instruction NO

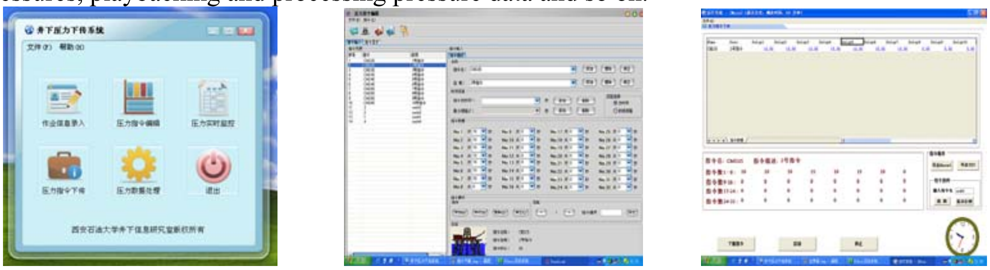
Time length of T2 (S)	20	25	30	35	40	45	50	55	60	65
Instruction NO.	CMD 20	CMD 25	CMD 30	CMD 35	CMD 40	CMD 45	CMD 50	CMD 55	CMD 60	CMD 65

4. Design and realization of the system

The system of instruction downlink includes generation for downlink pressure instructions and reception for the downhole pressure instructions. The pressure instructions are generated in the drill string, which controlled by software of ground computer. The downhole pressure instruction receiver acquire the pressure in bottom hole assembly (BHA), and the instruction which is decoded from the collected data.

4.1. Downlink pressure instructions generation

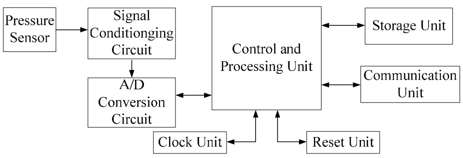
The opening and closing of the branch pipe generates pressure pulse in riser and drilling string, which is the basic principle of instruction generation. The controllable branch is realized by controlling the pulse valve in this branch, and the control process is as follows: first, the instruction's parameters are set in instruction editing software; second, the parameters are passed into pulse controller by the instruction download software and then electrical pulse is generated; finally, the pulse valve generates mud pulse in pipe by electrical pulse which is generated from the last step. The developed downlink instruction control software is shown in figure 3, among them figure 3-a is the main interface of control software; figure 3-b is the instruction editing software; figure 3-c is the instruction download software. In addition, the control software contains information input software, pressure real-time monitoring software and pressure data processing software. It can complete the tasks of recording drilling operation parameters, monitoring real-time pressures, playbacking and processing pressure data and so on.



a. Main interface b.Instruction editing interface c.Instruction download interfaceFigure3 The developed downlink instruction control software

4.2. Downlink pressure instructions reception

The structure of pressure instructions receiving circuit is shown in figure 4, which consists of pressure sensor, signal conditioning circuit, A/D conversion circuit, control and processing unit, clock unit, reset unit, storage unit, and communication unit. The principle of instructions receiving: The mud pressure signal is received by pressure sensor in BHA and changes into voltage signal. The voltage signals are sent to 24-bits high precision A/D converter after they are amplified and filtered by the signal conditioning circuit. Then, the digital signals are received by control and processing unit. There are two steps to process the digital signals in control and process unit. The first step is storing the original data by storage unit, and the next is processing them. Lastly, the instructions are decoded and passed on to the steerable drilling controller by control and processing unit. The clock unit is used to provide base times. In order to improve the reliability of the system, the reset unit is designed.



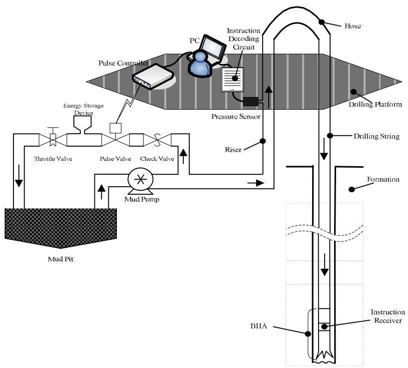


Figure4 The structure of pressure instructions receiving circuit

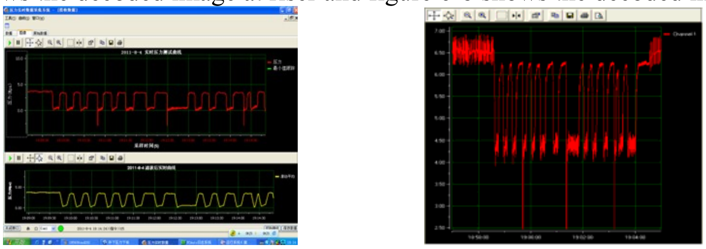
Figure5 Field test schemes

5. Field test

Field test schemes is shown in figure 5, the instruction receiver and the other drilling tools are assembled and put into borehole. A branch pipeline is laid between mud pump and riser. And then the check valve, pulse valve, energy storage device and throttle valve are install in the branch pipeline. In the control-room of drilling platform, the PC, pulse controller, instruction decoding circuit are connected. The pressure sensor connect with riser and instruction decoding circuit, and the pulse valve is connected with pulse controller. So, the pressure instructions downlink system is assembled completely.

After completing all of the preparatory works, the test is beginning. The downlink instructions are sent in different conditions of bit position, throttle valve opening size and pump stroke number. During the process of sending downlink instructions, the real-time pressure value and decoding results in riser can be displayed using the downlink instructions control software.

The table2 shows the decoding results. From the table, it can be seen that the gross number of instructions which are sent is 26 in different conditions are successfully decoded at riser and BHA. The figure 6 shows the decoding images when system send three instructions (CMD20, CMD30, CMD25)in the condition of bit position at 568m, throttle valve opening size at 26% and pump stroke at 70. Among them, figure 6-a shows the decoded image at riser and figure 6-b shows the decoded image at BHA.



a.Decoded image at riser b.Decoded image at BHA

Figure6 The decoding images

Table2 The decoding results table

Bit position(m)	Throttle valve opening size(%)	Pump stroke number per minute	Send instruction number	Decoded number at riser	Decoded number at BHA
568	26	60	2	2	2
		70	3	3	3
	30	60	3	3	3
		70	3	3	3
		90	1	1	1
131	26	60	4	4	4
		70	3	3	3
	30	60	3	3	3
		70	3	3	3
		90	1	1	1

6. Conclusion

(1). The software and hardware of downlink communication system for steerable drilling is developed successfully, and the reliability are proved by test.

(2). New instruction encoding method which uses pressure pulse falling edge and the time difference between adjacent drops pulses is put forward. And downlink communication system using this method improves the recognition ability of downlink instructions, so as to increase the reliability of information transmission in steering drilling.

Acknowledgements

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